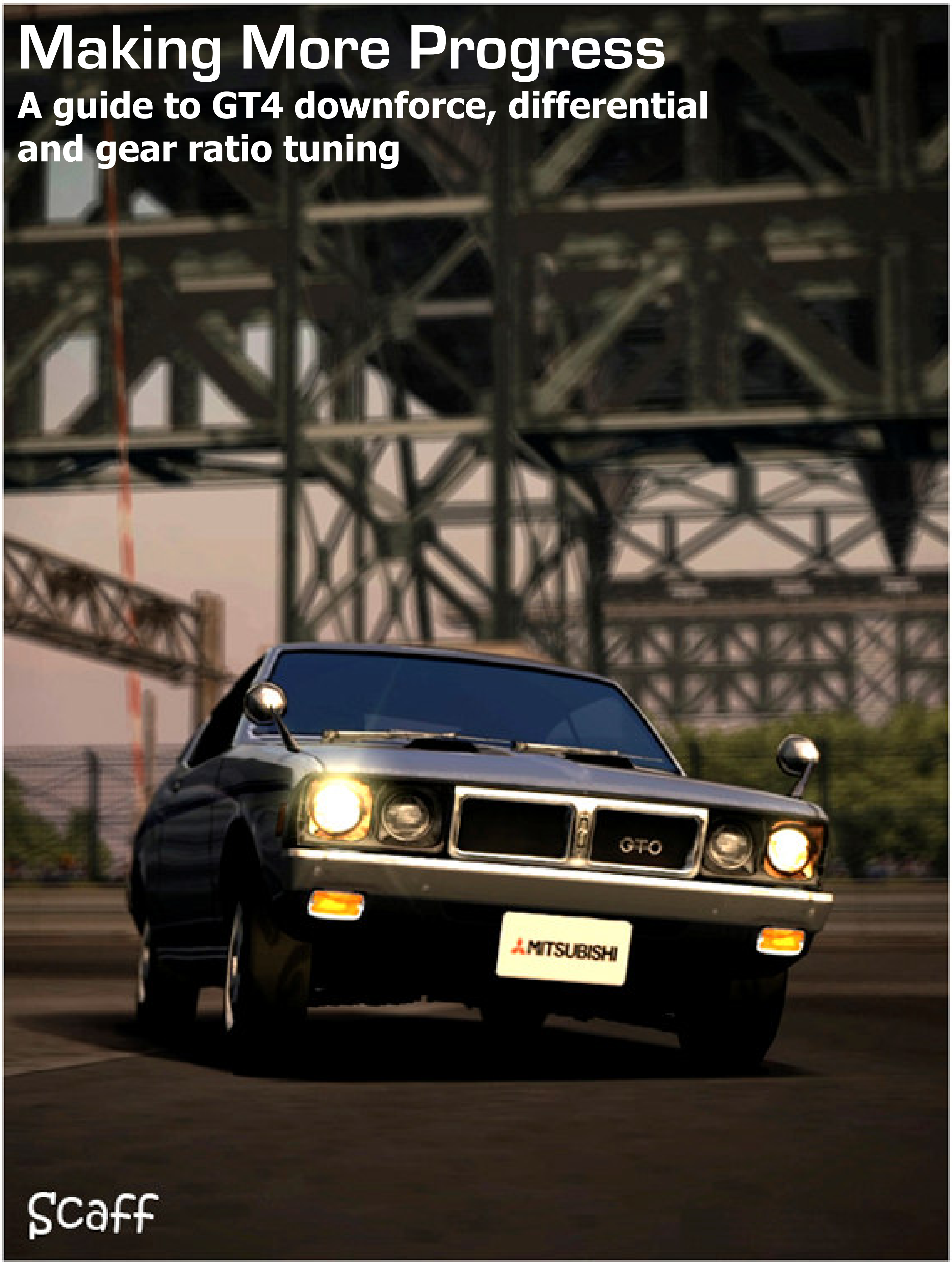
Making More Progress

A guide to GT4 downforce, differential and gear ratio tuning



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Welcome to the follow up to the original 'Making Progress', in that guide I covered the areas of suspension and brake tuning within Gran Turismo 4. It is designed to support the information contained in 'Making Progress' and as such should be used in conjunction with that guide.

In this guide I finish up in the area of settings by addressing some of the more complex area, such as differentials, downforce and gear ratios. Even given the sometimes more complex nature of these topics I hope that I have managed to cover them in a clear and concise manner, that will allow everyone to utilise these tuning areas.

As with 'Making Progress' the notes and techniques for tuning contained within this guide are not 100% real life, but rather the effects I have found from tuning in GT4. While a large amount of this does meet with real world practice, it is not a guide to tuning real cars and should not be taken as such.

In addition to the tuning areas I have included a guide to 'reading' a circuit to ascertain which corners are the most important, this helps significantly in tuning. Also included is another 'Example of a tune' to help put in focus the subjects covered in the guide.

In closing I once again hope that you find this guide interesting, and useful when tuning in GT4.

Regards

Scaff

Making Progress

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Downforce

Downforce is actually the effect achieved by the use of wings on a car, these wings are in theory exactly the same as the wings fitted to aircraft. They are however placed ‘upside down’ when compared to aircraft wings, so the effect is to produce downforce rather than lift (or up-force if you like).

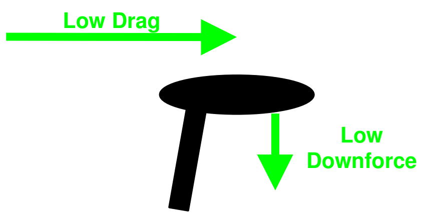
The benefit of this downforce is that it provides additional grip by loading the tyres with aerodynamic downforce; however the wings themselves are light. In effect you don’t add much to the overall weight of the car, but you do gain a downward load on the tyre which creates additional grip.

The downside to this is that the wings also produce drag, which makes the car harder to ‘push’ through the air, resulting in a reduction in top speed.

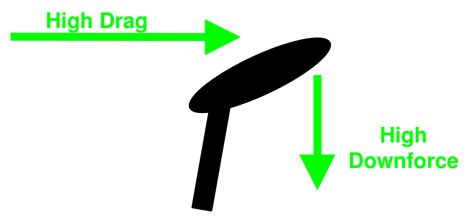
The interesting thing about aerodynamic downforce and drag is that it increases as the square of the speed divided by a constant. So if your car produces 50lbs of downforce at 40mph, it will not produce 100lbs at 80mph, but 200lbs. At 120mph the downforce would be 450lbs.

However you have to also remember that drag increases by a similar factor, so the more downforce you are creating the more drag you are also creating and the larger the impact will be on the cars top speed.

Changing the angle of attack of the wing varies the amount of downforce. The lower the angle of the wing, the lower the angle of attack and the less downforce and drag are created; as the angle increases the greater the angle of attack and the more downforce and drag are created.



Low Angle of Attack



High Angle of Attack

Overall Downforce Settings

Setting	✓	×
Less 'wing' (lower values)	Top speed increases.	Grip reduces. Braking distances increase. High speed stability reduces (subject to F:R aero balance).
More 'wing' (higher values)	Grip increases. Braking distances reduced. High speed stability improves (subject to F:R aero balance).	Top speed reduces. Harder suspension settings required.

Note: The increases and reductions here are all relative to the previous downforce setting. In addition the more 'wing' you use and the more downforce generated the firm the suspension on a car must be set, this is to avoid the chance of the additional load causing the car to bottom out.

As was discussed above, the effects of downforce and drag increase with speed and are only effective at higher speeds (approx. 60mph/100kmh +), with the effects increase as speed does).

At these higher speeds the front to rear downforce balance becomes the dominant force in determining the cars balance. This means that a cars low speed handling balance can be set in one way at lower speeds through conventional suspension settings and another balance can be set for higher speeds through the use of downforce (this is know as the aero balance). You could therefore have a car with a balance towards oversteer at lower speeds and an understeer balance at higher speeds.

Caution does need to be exercised here as speed increases or decreases you move from one balance to the other, should this occur as you are cornering the effect of a sudden switch in the cars balance may well result in a loss of control. As with all tuning this needs to be balanced for the car and track

Front Downforce Settings

Setting	Effect
More Front 'wing' (higher value)	Decreases understeer
Less Front 'wing' (lower value)	Increases understeer

Rear Downforce Settings

Setting	Effect
More Rear 'wing' (higher value)	Decreases oversteer
Less Rear 'wing' (lower value)	Increases oversteer

Limited Slip Differential

Limited Slip Differentials are an area of tuning that often cause a huge amount of confusion, both in how they work and how (and if) they should be set.

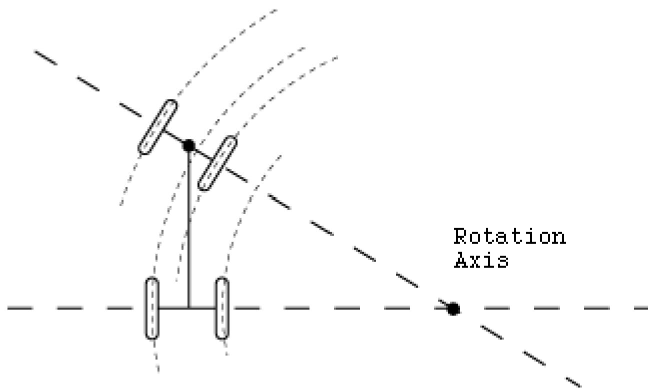
I hope that the following will help to clear up both areas.

What is a differential (open and limited slip)?

All cars have a differential working on the driven wheels (four-wheel drive cars obviously have two differentials, one for each set of driven wheels) serving a number of different functions.

They exist to transfer power from the drivetrain to the wheels, acts as the final part of the 'gearing' before power reaches the wheels (the wheels themselves are arguably the final 'gear' but this is covered in the later section on gear ratios).

The final function of the differential is however to allow the driven wheels to rotate at different speeds (which is not an issue for non-driven wheels). This is needed because as a car turns the wheels nearest to the corner apex will travel a shorter distance that the outside wheels.



This is all fine when the car is operating below its limits. However a standard (or open) differential, as fitted to the majority of road cars, will distribute the power between the driven wheels evenly, unless one of the wheels begins to slip. As an open differential will always send the torque down the path of least resistance, should one of the tyres slip (and therefore offer little resistance), the open differential will send all the power to it.

Imagine coming out of a tight corner on a track and applying the power slightly too quickly, one of your driven wheels begins to slip, and then to make matters worse the open differential send all the available power to the wheel that is already slipping. The end result would be that of spinning all the power away in a cloud of tyre smoke.

This is where the limited slip differential comes into play, it will allow a wheel to take up to a certain percentage of the available power, but no more than that percentage. So in our example above, the wheel spinning as we came out of the corner would be allowed to 'steal' a certain percentage of the power, but the rest would be sent to the other wheel. This would even out the power delivery and allow a more balanced delivery of the power on corner exit.

However, limiting the slip does have its downslide. Should the limit be set incorrectly it may not allow the wheels to rotate 'differently' enough to turn the corner (which is one of the main reasons the differential exists in the first place). If they can't rotate at different enough rates then the car will become reluctant to turn. The tighter the corner the worse this issue will be (as the greater the difference between the rates the wheels need to rotate at).

In the simplest sense, the Limited Slip Differential is a balancing act, between allowing the wheels to rotate freely from each other to ensure the car will turn, but locking to ensure that neither of the wheels 'steals' all the available power.

Types of Differential

It is worth taking a moment to look at the types of differential available in GT4 and what options they give you.

1-way LSD

The 1-way LSD operates only under acceleration and is widely used on front wheel drive cars. While it is not adjustable in any way it is a good choice for a front wheel drive car when tuning, and in most cases I would recommend fitting one instead of the Fully Customisable LSD.

1.5-way LSD

The 1.5-way LSD operates under acceleration and to a limited degree under deceleration as well. Again it is not adjustable and is a good choice for those wanting the benefits of an LSD without the hassle of setting it up (but where's the fun in that). The effects of the LSD under deceleration are not as strong as the effects under acceleration with the 1.5-way LSD

2-way LSD

The 2-way LSD operates under both acceleration and deceleration, and does so to the same degree. As it is not adjustable it can cause problems with the cars ability to turn under braking, as such it does not suit all driving styles, particularly those drivers who like to trail brake may find it problematic. I would not generally recommend the use of a 2-way LSD.

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Fully Customisable LSD

The reason we came here, the Fully Customisable LSD allows total control of the level of initial operating torque for the differential as well as the locking effect under both acceleration and deceleration. This control will effect the driven wheels of the car, so for a four-wheel drive car you will have total control of the differential settings for both the front and rear wheels.

Limited Slip Differential Settings

Initial Torque

The initial torque value controls the differential as a whole, and as such it will act to increase or decrease the acceleration or deceleration settings themselves. It also determines how responsive the differential itself is, and as such can be used to help control how manoeuvrable the car is.

Initial Torque Settings

Setting	✓	✗
Opening (lower values)	Improves the cars manoeuvrability.	Reduces the effect of the accel. and decel. LSD settings.
Locking (higher values)	Increase the effect of the accel and decel LSD settings up to a point, after which the effect will decrease.	Reduces the cars manoeuvrability.

Note: Setting the initial value to 5 will result in the LSD acting as an 'open' differential and a setting of 60 will result in the LSD acting as a 'locked' differential. Either of these values (5 or 60) will make the Accel and Decel settings redundant as the differential is now either open or locked.

Note: The point at which raising the Initial Torque will stop increasing the effect of the Accel and Decel settings and begin to decrease the effect, varies from car to car. This can make using the Initial Torque setting difficult and small changes are recommended.

Accel. Settings

Controls the locking level of the LSD under acceleration, it can be used to control wheel spin when exiting a corner, but will also limit the cars ability to turn as the throttle is applied if it is set too high.

Accel. Settings

Setting	Effect
Locking (higher value)	Increases traction out of corners by limiting wheel spin. Limits the car's ability to turn, particularly in tight corners.
Opening (lower value)	Reduces traction out of corners by increasing the chances of wheel spin. Improves the car's ability to turn, particularly in tight corners.

Decel Settings

Controls the locking of the LSD under deceleration it can be used to improve a cars stability when braking into a corner, but will also limit the cars ability to turn under braking if set to high.

Decel Settings

Setting	Effect
Locking (higher value)	Increases stability when decelerating into a corner. Limits the car's ability to turn.
Opening (lower value)	Reduces stability when decelerating into a corner. Improves the car's ability to turn.

It should always be remembered when tuning the LSD that the effect will only be applied to the driven wheels, and that a Limited Slip Differential will act as an open differential up to the point at which is set to start limiting the amount of slip. For this reason the effects can be difficult to read at first, but the more you experiment with LSD settings the more valuable a tool it will become. Particularly when dealing with very high horsepower cars or cars with a high power to weight ratio.

It is also worth noting in closing this section that certain cars that come fitted with very sophisticated differentials as standard, such as the Nissan Skyline GT-R can actual suffer by the fitting of an LSD.

Variable Centre Differential

The Variable Centre Differential is a device that can be fitted to four-wheel drive cars to allow the torque split between the front and rear wheels to be set at a specific ratio.

Once fitted the VCD can be set to provide a more rear wheel drive balance to a four-wheel drive car, this can help to resolve some of the inherent understeer issues that characterise four-wheel drive cars.

VCD Settings

Setting	Effect
Rear Bias (lower values – min 10)	Less torque sent to the front wheels. Car will behave more like a rear wheel drive car the lower the value is set.
Centre Bias (higher values – max 50)	More torque is sent to the front wheels. Car will behave more like a four-wheel drive car the higher the value is set .

Note: The figure the VCD is set to relates to the percentage of torque sent to the front wheels. The available settings therefore provides a range from Front 10% : Rear 90% to Front 50% : Rear 50%.

The VCD should be set to provide the required balance for the road surface being driven on and the handling style required. As a general rule of thumb track settings would carry a rear bias and lower grip conditions (gravel, wet tarmac, snow and ice) a more central bias.

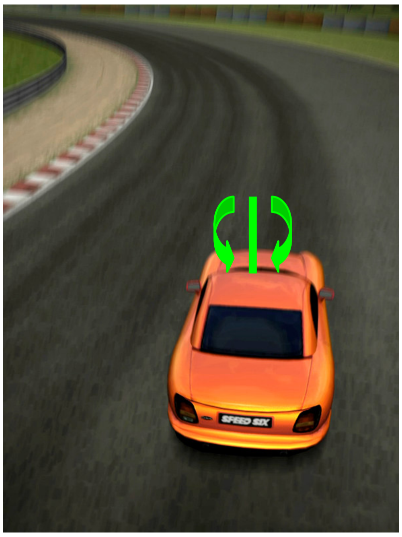
Setting the VCD would normally be done early on in the tuning process, as any changes will have a major effect on the suspension settings.

As with the Limited Slip Differential, certain cars that come fitted with very sophisticated differentials as standard, such as the Nissan Skyline GT-R can actual suffer by the fitting of a VCD.

Active Yaw Control

The Active Yaw Control is a very sophisticated type of differential that by controlling and varying the split of torque between the left and right of the car can control and manage the cars rate of yaw.

Yaw itself is defined as the rotation of a car around its centre axis, as viewed from above, and is an excellent indicator of the car's balance. Many active safety devices (such as stability control systems) measure yaw as an indicator of control loss.



The downside to the AYC is that it is only available for a very limited range of cars from Mitsubishi, and as such your option for fitting it are limited to a handful of cars. It is however a very valuable tool for these cars, particularly when driving on gravel surfaces.

AYC Settings

Setting	✓	✗
Lower Values	Decreases the cars ability to turn.	Reduces Oversteer.
Higher Values	Increase the cars ability to turn.	Increases oversteer (dramatically at very high settings).

Use of the AYC can effectively allow the car greater rotation from less steering input and as such is valuable in situation were steering response in reduced, such as gravel or other lower traction situations.

However great car is required because as the settings are increased the car wants to rotate more readily and as such can snap very quickly into dramatic oversteer.

Gear Ratios in GT4

The subject of gear ratio setting in the Gran Turismo series is one that causes wide-ranging debate and discussion. How should they be set? What relationship does engine power have to the ratios? When should you change gear?

I hope that the following section of this guide will help answer these questions, but please do keep in mind that what follows is based on my experiences with the Gran Turismo series and what I find works for me.

Before we cover the effects of changing the gear ratios themselves in GT4, I'm going to run through a number of topics that are not specifically required to set the gear ratios. However I believe they help to explain what is happening along the car's drive train and give a more in depth understanding of its workings.

Speed per 1,000rpm

The ability to calculate MPH per 1,000 rpm from Gear ratios is a very useful skill to have. It can be used to see more visually the effect of changing individual gear ratios and/or the final drive ratio has on the car's performance.

It should be noted that the speeds given here are raw data and while quite accurate at lower speeds, are not capable of taking into account bhp vs. aero drag when calculating a car's maximum speed.

The following is an example of how to calculate mph per 1,000rpm for a Toyota Celica SS-II, I used this car as an example simply because I drive one and as such was able to verify the accuracy of the calculations.

First you need to get the correct wheel and tyre diameter from the driver wheels tyre size (only the driven wheel needs to be calculated).

Use the following Formula

Diameter = Width (mm) * sidewall height (%) / 25.4 * 2 + wheel diameter

For example 205/45R-17

205 * 0.45 / 25.4 * 2 + 17 = 24.26"

This information can be difficult to get for some cars in GT4 as the game does not (that I have found) provide it, google is your friend here.

We can now calculate the MPH per 1,000 rpm for each gear using the following formula

MPH per 1,000RPM = tire diameter / 336 * 1,000 / (gear ratio * final drive)

The Celica gear ratios and Final drive are as follows

1st 3.17
2nd 2.05
3rd 1.48
4th 1.17
5th 0.92
6th 0.82

Final Drive 4.53

So if we use our formula to calculate the MPH per 1,000 rpm for 1st gear we get

24.26 / 336 * 1,000 / (3.17 * 4.53) = 5 mph per 1,000rpm

Using the same formula for the rest of the gears we get

1st – 5.03 mph per 1,000rpm
2nd - 7.78 mph per 1,000rpm
3rd - 10.77 mph per 1,000rpm
4th - 13.62 mph per 1,000rpm
5th - 17.33 mph per 1,000rpm
6th - 19.44 mph per 1,000rpm

As mentioned earlier, these figures do not take into account the power required to overcome aerodynamic drag in calculating maximum vehicle speed. These are simply gearing speeds, take the Celica above, from the gearing calculations the maximum speed would be (at a red-line of 8,000rpm) 155mph, drag however limits this to around 140mph.

Now if we were to change the final drive ratio in the car above from 4.53 to 5.00 and used the formula to calculate the new speeds we would get the following.

1st – 4.56 mph per 1,000rpm
2nd - 7.05 mph per 1,000rpm
3rd – 9.76 mph per 1,000rpm
4th – 12.34 mph per 1,000rpm
5th – 15.70 mph per 1,000rpm
6th – 17.61 mph per 1,000rpm

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If instead we were to change the final drive to 4.00 and used the formula to calculate the new speeds we would get the following.

1st – 5.70 mph per 1,000rpm
2nd – 8.81 mph per 1,000rpm
3rd – 12.20 mph per 1,000rpm
4th – 15.43 mph per 1,000rpm
5th – 19.62 mph per 1,000rpm
6th – 20.02 mph per 1,000rpm

What we can see by changing the final driver ratio is that as we increase the final drive value the speed per 1,000rpm drops (and therefore the maximum in-gear speed); and as we reduce the final drive value the speed per 1,000rpm increases (and therefore the maximum in-gear speed).

It's also clear that changing the final drive ratio effects all the individual gear ratios. You will get the same effect if you change a single gear ratio itself, but it will only effect that gear.

However before we all rush out and increase these values to get the maximum potential speed out of each gear we need to look at how these changes effect acceleration, and this will be covered in the next section.

I do however hope that the above helps explain the relationship between the final drive/axle ratio and the gear ratios and how they work together, also how the tyre diameter has a major impact on gearing.

It possible to use the above to construct an excel spreadsheet that will automatically show the effect of changing gear ratios on theoretical speed.

When to Change Gear

An area of constant discussion and argument, the subject of when is the optimum point to change up is one again that can help us understand the relationship between gear ratios and the engine, and better understand the drive-train as a whole.

Many people advocate changing gear at the point peak engine power is reached (with many disagreeing in regard to this being bhp or torque), some suggest the red-line, others still maintain it should be the point at which the next gear would reach peak power when you change up.

Ford and ex-General Motors power-train engineer, Ed Lansinger, wrote one of the finest papers I have read on this subject. The paper in question is reproduced below, please note that it was originally written for a Dodge Neon website and also includes a number of additional comments at the bottom.

Torque vs. Power – Author Ed Lansinger

First, a clarification: torque is no more real than power. The DOHC puts out 133 ft-lb of ground-pounding torque, but I've seen some older Neons that are leaking torque and you have to avoid driving behind them because the torque, once leaked, is slippery. Don't bother picking it up and adding it to your engine as it degrades quickly and will take you out of Stock class. Consider torque and power as concepts used to describe how things interact to produce movement and how "energy" (another concept) is transferred.

Both torque and power can be observed "directly". Think of slowing a free-spinning tire with your hand. Feel the tug on your palm and the tension in your arm? That's a measure of torque, the torque the tire experiences as a result of your palm slowing it down. Feel the heat build up from friction? That's a measure of power.

Incidentally, water brake dynamometers get a direct measurement of power by measuring the increase in the temperature of water flowing past a propeller spun by the engine under test. You can solve for torque if you know engine RPM.

Maximum Acceleration vs Torque

I'd like to think that torque is an intuitively easier concept to understand. If that were true, though, then more people would understand the relationship between torque, horsepower, and vehicle acceleration. In reality, none of it is intuitive. If it were, Newton wouldn't be considered the Really Great Guy that he is.

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The classic mistake is to conclude that the fastest way down, let's say, a 1/4 mile drag strip is to keep the engine RPM at the torque peak (or as close as possible). The technique is usually stated as "shift just after the torque peak", or "shift N RPM above the torque peak so you are N RPM below the torque peak in the next gear when you finish the shift".

Unfortunately, *engine* torque does not tell you the full story. What matters is the torque *delivered to the tires*, including the effects of the transmission. We all know a car does not accelerate as hard in second gear at peak torque RPM as it does in first gear. The transmission amplifies or multiplies the torque coming from the engine by a factor equal to the gear ratio. So to determine how much the car is accelerating at a particular instant, you have to know both the torque output of the engine as well as the gear ratio.

To figure out your shift points knowing only torque, generate tables of transmission output torque vs. RPM for each gear. To get transmission output torque, multiply the engine torque by the gear ratio. You are simply comparing gear to gear, so the final drive ratio can be ignored. You may also need to know the relationship between RPM in one gear and RPM in another gear (which is RPM * (gear2ratio/gear1ratio) at any particular vehicle speed.) Then it's easy to see what shift points to choose to maximize your transmission output torque at all times.

Here's an example for the 1999 Neon DOHC engine with a five-speed manual transmission. Before you flame, understand that I do not have an accurate torque curve for this motor. I'm estimating visually from the curve printed in the 1999 brochure, which is seriously flawed (it makes a lot more sense if the torque curve is shifted to the right 1000 RPM). I get:

Engine		Transmission output torque (ft-lb):				
		1st Gear (3.54)	2nd Gear (2.13)	3rd Gear (1.36)	4th Gear (1.03)	5th Gear (0.72)
RPM	Torque (ft-lb)					
1,000	50	177	107	68	52	36
1,500	65	230	138	88	67	47
2,000	80	283	170	109	82	58
2,500	92	326	196	125	95	66
3,000	104	368	222	141	107	75
3,500	114	404	243	155	117	82
4,000	120	425	256	163	124	86
4,500	125	443	266	170	129	90
5,000	130	460	277	177	134	94
5,500	133	471	283	181	137	96
6,000	130	460	277	177	134	94
6,500	122	432	260	166	126	88
7,000	110	389	234	150	113	79

(note: peak torque is at 5500 RPM, peak horsepower is at 6500 RPM)

Without graphing, there's something immediately apparent: in any gear, at 7000 RPM, the transmission torque output is always higher than at any RPM in the next gear up. What this means is, for this car:

*** Shift at the redline, not at the torque peak!**

Walk through an example. You're hammering down the track in 1st gear. Engine RPM is 6000, just past the engine's torque peak. Do you shift? Well, if you do, the engine will be pulled down to 3600 RPM, and 2nd gear will send 246 ft-lb of torque to the wheels (actually, to the differential first, which amplifies the torque by a constant factor and sends it to the wheels). Don't you think it would be better to hold it in first gear? Torque is dropping off, but it's still 389 ft-lb at 7000 RPM, right before the 7200 RPM redline. So, for this powertrain, first gear is *always* the best deal for acceleration, at any speed, except that you can't accelerate past the redline.

The 1-2 shift at 7200 RPM pulls the engine down to 4400 RPM, where 2nd will deliver 265 ft-lb of torque. Not only did you win by maintaining the high torque of 1st all the way to 7200 RPM, you are now better off in second gear.

Same thing goes for the 2-3 shift. 2nd gear output torque at the redline is still greater than 3rd gear output torque at any engine speed, so you wind her out as far as she'll go before you shift to 3rd. Same for the 3-4, same for the 4-5. But, you ask, isn't your acceleration greatest at the torque peak? Yes, it is! But only within that gear. The next gear down will give you even greater acceleration at the same speed, unless the vehicle speed is too high for that gear.

To use engine torque to understand how your car performs, you MUST include the effects of the transmission.

Maximum Acceleration Vs. Power

OK, so what about power? As has been noted by a previous contributor, Power (hp) = Torque (ft-lb) * RPM / 5252. Note that power is also force * velocity, specifically:

Power (hp) = Force (lb) * Velocity (MPH) / 374

That's net horsepower, which is engine power minus losses like transmission and tire friction. The force is the sum of the longitudinal forces at the contact patches of the two driven tires.

Hmmm... P = F * V ...rearrange to get F = P / V ...

that means that you get the maximum force pushing the car if you maximize your *Power* at any given velocity. This gives us another useful rule:

*** Shift to maximize engine POWER, not engine torque!**

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This is *exactly* the same as saying "shift to maximize transmission output torque". But it's a little easier to apply. Here's how.

Using the torque information above, I get the following power curve:

RPM	HP	
1000	10	
1500	19	
2000	30	
2500	44	
3000	59	
3500	76	
4000	91	
4500	107	
5000	124	
5500	139	(peak torque)
6000	149	
6500	151	(peak power)
7000	147	

The tires don't see quite these numbers due to [friction and aerodynamic] losses, but I'm going to assume that the losses are comparable from gear to gear and that the overall shape of the power curve remains the same.

Applying the maximum power rule, we'd like to race down the 1/4 mile with the engine always as close to 6500 RPM as possible. If we had a continuously variable transmission, the lowest E.T. would be achieved by keeping the engine dead on 6500 RPM. 5500 is not the best; at any vehicle speed, the engine would put out more torque but the transmission will have a less advantageous gear ratio, so you get a net loss of force to the tires. Apply P = F * V or P = T * RPM to prove this.

Since the Neon doesn't have a CVT, we have to shift. The shift points are pretty easy to determine. In fact, you don't really need to know anything about the gear ratios of the different gears, which is why power is sometimes easier to understand than torque.

I'm going to assume that the DOHC puts out at least 145 horsepower at the redline (7200 RPM). Shifting at the redline in each gear should drag the engine down as follows:

shift	RPM drop	Horsepower change
1->2	7200->4700	145->114
2->3	7200->4600	145->110
3->4	7200->5500	145->139
4->5	7200->5000	145->124

(I derived this, but all you really need to do is drive the car, shift, and find out where the motor lands)

Note - and this is important - the transmission does not amplify power.

**Power in = power out, minus losses
(which are low for a manual transmission).**

This is predicted by the law of conservation of energy.

Is 7200 the correct shift point? It would *not* be the correct shift point if the engine was making more power in the new gear than the old gear. That would mean that you should have shifted earlier. But in this case, the power output at redline is always greater than the power output after the shift. So it's the best performance you can get.

A more rigorous way of doing this is to graph horsepower vs. velocity in each of the gears. If power in one gear drops below the horsepower of the next gear at a particular MPH, then that MPH is where you should shift, otherwise shift at the redline.

I leave as an exercise for the reader the following: predicting shift points based on engine torque, RPM, and gear ratio gives the same results as predicting shift points based on power and vehicle velocity.

Exceptions

There are no exceptions; a car running at its (net) power peak can accelerate no harder at that same vehicle speed. There is no better gear to choose, even if another gear would place the engine closer to its torque peak. You'll find that a car running at peak power at a given vehicle speed is delivering the maximum possible torque to the tires (although the engine may not be spinning at its torque peak). This derives immediately from first principles in physics.

However, note the following: - Transmission losses are not shown on engine power curves. The net power curve (power delivered to the ground) may have a different shape or even a different peak RPM as a result. This would result in different shift point. Best results are obtained from a power curve measured by a chassis dynamometer. - The discussion above assumes negligible tire slip. If you exceed the maximum traction available from the tires, then additional power doesn't help. That's why it's sometimes no loss at all to shift early when the tires break loose, and in fact it can be a benefit.

More exceptions: another view (by Maciek S. Kontakt)

Yes, there are exceptions. The Neon engine is not a responsive engine as its band is very narrow. The band is between peak torque and peak power and it is only 1000rpm. This engine is designed with focus on speed and not on acceleration as much. Peak power will tell only how fast you can go because beyond peak power there is almost no acceleration and that is your top speed deteremination on a particular gear.

In addition to that there are very responsive engines like BMW 3 series (not M3) that actually you shift to keep peak torque between points of shift and if you want to accelerate faster you are not supposed to reach peak power (proven on my own BMW of that type). If you have engine with wide band your explanation may not hold true. YOU WILL FIND many points where torque on higher gear would be higher that you were at lower gear only at high rpms. That depends of course how close are gearing ratios put into transmission.

Optimization for speed and optimization for acceleration are very different. It is even not true what is said by many authoritative sources (books written by racers) that you upshift at point where torque value would be lower than on higher gear. It is more complex that that and you have to refer to gain of speed on both gears if you changed rpms (accelerated). That is because torque curve is not flat and it can be differently "sloped" on ascending and descanding parts. The field (space) under that curve is more relevant to the shift points than values on particular points of the curve. That's pure mathematics and physics which takes... classes at university and does not take track time in a race car. Ask engineers rather than technicians or racers.

By the way, the main principle of physics is: to accelerate there is unbalanced force required (in some places in this world you will not graduated from high school if you at least do not memorize that). Torque represents force. Power is derived from torque and it represents force causing motion. No motion - no power. Initial cause of power is force. Power on the combustion engine diagrams past peak torque grows only because rpms grow (power is direct multiplication of torque and rpms). Once torque of engine falls sharply, rpms growth cannot overcome that and power will also fall. Simple as that. F1 and Indy bolids are build for top speed on long straights. That is why their engine designers struggle for high rpms to achieve high peak power (and power past that point a bit). They accelerate well too but that is not neccesarily primary goal. When there is acceleration required there will be less stress on peak power (read rpms), but on force that is torque curve shape.... given you do not need to accelerate to very high speeds because for example your road/track is full of tight bends rather than straights. Supercharged units have torque almost entirely flat so you again may want to shift at the end of any curve (power or torque), but that's another example justified.

To the Point

Torque and power are (almost) flip sides of the same coin. Increasing the torque of an engine at a particular RPM is the same as increasing the power output at the same RPM.

Power is just as useful and relevant in determining vehicle performance as is torque. In some situations it's more useful, because you may not have to play with gear ratios and a calculator to understand what's going on.

A car accelerates hardest with gearing selected to stay as close as possible to the engine *power* peak, subject to the traction capability of the tires.

Not all cars should be shifted at the redline for maximum performance. But it's true for many cars. You can determine optimal shift points by graphing horsepower vs. velocity or transmission torque vs. RPM. Engine torque alone will not determine shift points.

Making Progress

Conclusion

The above piece gives us a lot to think about, but I would like to focus on two main points.

The first is that no single rule can be applied when it comes to determining a shift point for a given car, you need to look at the power and torque curves (which GT4 does show to us). And you also need to consider how the power and torque is going to be delivered in any given gear in comparison to the next gear.

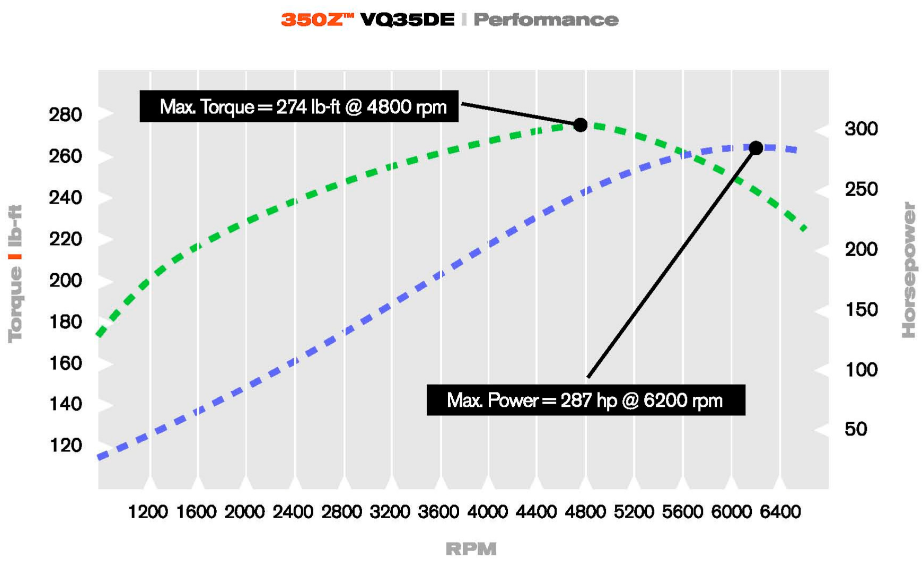
The simplest rule of thumb is that you should only change gear when moving to the higher gear will give you more power and/or torque.
The second point is that torque is multiplied by the drive train itself.

To find an approximate figure for torque delivered at the wheels we use the information above as a starting point, in that you multiply the engine torque for the current engine rpm by the gear ratio, you then need to multiply this figure by the final drive ratio.

The resulting figure is the approximate level of torque delivered at the driven wheels; to obtain an approximate figure for each wheel divide by the number of driven wheels.

Remember that this is a figure without any drivetrain losses taken into account and will simply be a maximum possible figure.

Lets look at an example using a Nissan 350Z and its first gear ratio of 3.79 and final drive ratio of 3.54.



In first gear at 2,000rpm the torque at the wheels is approx. 3,019lb-ft (225lb-ft * 3.79 * 3.54) or approx. 1,509.5 lb-ft per tyre (3,019 / 2).

However at peak torque in 1st gear (4,800rpm) this rises to 3,676 lb-ft or 1,838 lb-ft per tyre. An increase of 657 lb-ft in total, or 328 lb-ft per driven wheel. This increase in torque, particularly if delivered to the driven wheels quickly may well result in a loss of traction and wheel-spin. The multiplying effect of

the gear ratio and final drive is why wheel spin is more likely in lower gears than in higher gears.

Now looking at all of this it becomes clear that if we increase the value of a single gear ratio it will produce more torque at the wheels for that gear. And if we did the same for the final drive it would produce more torque at the driven wheels for all gears.

This increase in torque from using a high value will produce more torque at the driven wheels and provide more acceleration, but it also increases the chances of overloading the tyres limit and creating wheel spin.

However if we now think back to the section on mph per 1,000rpm, there we found that using higher values for the gear ratios or final drive ratios resulted in a lower overall maximum speed.

This is the balance you have to achieve with gear ratios, the higher the values the better the acceleration, but the lower the overall speed of the car.

Stock Gearbox Vs. Fully Customisable Gearbox

In GT4 it is sometimes advisable to avoid using the Fully Customisable Gearbox with certain cars, particularly those that produce a high level of torque.

The standard ratios in the Fully Customisable Gearbox are not the same as the stock gear ratios found in the stock gearbox. In every example where I have compared Stock vs. FC the ratios in the FC box are closer (the values are higher) and in a lot of cases it is not possible to match the stock values.

A good example of a car that this causes a problem for is the Ford GT, with peak 500 lb-ft of torque produced at 3,700rpm it can be difficult to control at the best of times, requiring a very gentle touch with the throttle. The standard gearbox ratios are also already quite close, installing the Fully Customisable gearbox only makes matters worse as the ratios are much higher than in the standard gearbox and its not possible to reduce the values to a point near the standard ratios.

As a result the Ford GT with a Fully Customisable gearbox is almost impossible to drive on most tyres, but a quick swap back to the standard gearbox resolves most of these power deliver problems.

Remember the Fully Customisable gearbox is not always the best option.

Setting Gear Ratios

Gran Turismo 4 gives us a number of different methods of setting gear ratios, including a very easy to use Auto setting tool. I'm going to look at each 'level' of gear ratio setting that can be used.

The Auto slider

The Auto slider allows very quick and easy changes to be made to the individual gear ratios, but does not change the final drive ratio. Changes made by using the Auto slider will generally be less 'severe' that changes made directly to the Final Drive ratio. As the Auto slider also changes the individual gear ratios together it normally sets a good balance between each ratio.

It's a great tool as it allows quick and easy changes to be made to the ratios by anyone, and as the effects are not drastic its quite safe to experiment with.

Its also worth keeping in mind that changing the value of the Auto slider changes the range of available values for the Final Drive Ratio and the Individual gear ratios.

Auto slider settings

Setting	✓	✗
Close (lower values)	Increases Acceleration.	Reduces Top Speed. Increases wheel spin.
Long (higher values)	Increase Top Speed. Reduces wheel spin.	Reduces Acceleration.

Note: Setting the Auto value too high can actually reduce top speed, as the car may not be able to accelerate through the aero drag at higher speeds. If this occurs reduce the setting.

Final Drive

The Final Drive setting, sometimes called the Axle Ratio, is effectively the gear ratio of the differential, as such any changes to the Final Drive Ratio will have a dramatic effect on the car. This is because (as we discussed previously) the Final Drive ratio has a multiplying effect on the individual gear ratios when calculating driven wheel torque and in-gear speeds.

As such changes to the Final Drive ratio will normally have a much greater effect on the cars performance that changes to the Auto slider.

Final Drive settings

Setting	✓	×
Long (lower values)	**Increase Top Speed. Reduces wheel spin.**	**Reduces Acceleration.**
Close (higher values)	**Increases Acceleration.**	**Reduces Top Speed. Increases wheel spin.**

Note: Remember that the changes to the Final Drive ratio will effect the performance of the car in every gear.

Individual Ratios

It is possible to change the setting of each available gear ratio itself. In theory this is no different to changing the Final Drive ratio, just that the effect will be for the selected gear only and will still be affected by the final drive ratio itself.

Take care when changing the individual ratios as its possible to focus too much on a single gear and throw out its relation to the gear above of below. The result can be a sudden drop in acceleration when you change gear.

It is rare to need to play around with the individual ratios themselves, but it can be a useful tool at times. Just remember if you mess things up, you still have the ability to hit the default button and start again.

Individual Gear settings

Setting	✓	×
Long (lower values)	**Increase Top Speed. Reduces wheel spin.**	**Reduces Acceleration.**
Close (higher values)	**Increases Acceleration.**	**Reduces Top Speed. Increases wheel spin.**

Note: Remember that the changes to the individual gear ratios will effect that gear only, but may throw it out in relation to the gears above and below.

Making Progress

Overall

It should always be kept in mind that the effects of the gear ratio tools are cumulative (this should be clear by now). If you set the auto slider to 25 and then set the final drive and individual gear ratios as low as they could go, you would have a car that accelerate very rapidly (with lots of wheel spin), but have a very low top speed. If you try this in an M3 CSL you end up with a top speed of approximately 52mph.

The aim with most transmission tuning is to maximise both your acceleration and top speed for a given circuit, I normally aim to tune the gears so the car will hit its top speed just as you get to the braking zone of the longest straight. I also aim for this to occur in the highest useable gear, and trial and error will help you judge what this is.

The 'Tranny' Trick

The 'tranny' trick is a gear tuning method that some tuners swear by, and just as many people say doesn't make a difference.

I must confess it's not something that I personally use, but I have included it here so that you can try it.

You start by adjusting the Final Driver Ratio to the highest value (normally 5.00 or 5.50) and then moving the Auto slider to 25 and then all the way back to 1. Leaving the Auto slider set at one you now adjust the Final Drive ratio to a setting that will meet the needs of your car and the track.

Reading the Circuit

The Theory

When driving or tuning a car for a specific track it very quickly becomes clear that certain corners are more important than others are. These important corners are the ones that can make or break a good lap time or really push the car to the limits of is potential.

While it is perfectly possible to discover these corners through track time and trail and error is quite handy to be able to identify them early on and be able to focus on them from the start of tuning or driving.

Various methods have emerged over the years for prioritising corners on a track, the one I use is based on a method first outlined by Alan Johnson in his 1971 book 'Driving in Competition'.

He proposed that when you look at a track you would find only three types of corners:

Type 1	-	One that leads onto a straight
Type 2	-	One that comes at the end of a straight
Type 3	-	One that connects two other corners

Type 1 corners are of more importance than Type 2 corners, which in turn are more important than Type 3 corners.

Over the years various people have taken this method and revised it further, each adding a little more to it.

One of the most commonly used variations (and my preferred one) Is to then break each of these three corner type down further into fast, medium and slow corners. With fast being the highest priority and slow the lowest.

The reasoning behind this is two-fold. First you have more time to gain or lose on a fast corner, corner at 90% of the car's limit on a 50mph corner and you are doing 45mph, do the same on a 100mph corner and you are doing 90mph. You lose and extra 5mph on the faster corner by being the same amount under the cars limit. This is of course even more critical on a corner that leads to a straight, as it will have a huge effect on the maximum speed you can reach on the straight.

The second reason behind sub-dividing corners into speeds is that generally people will be slightly more cautious on faster corners than slower ones, so if you can master them you have an advantage over a more cautious driver.

Making Progress

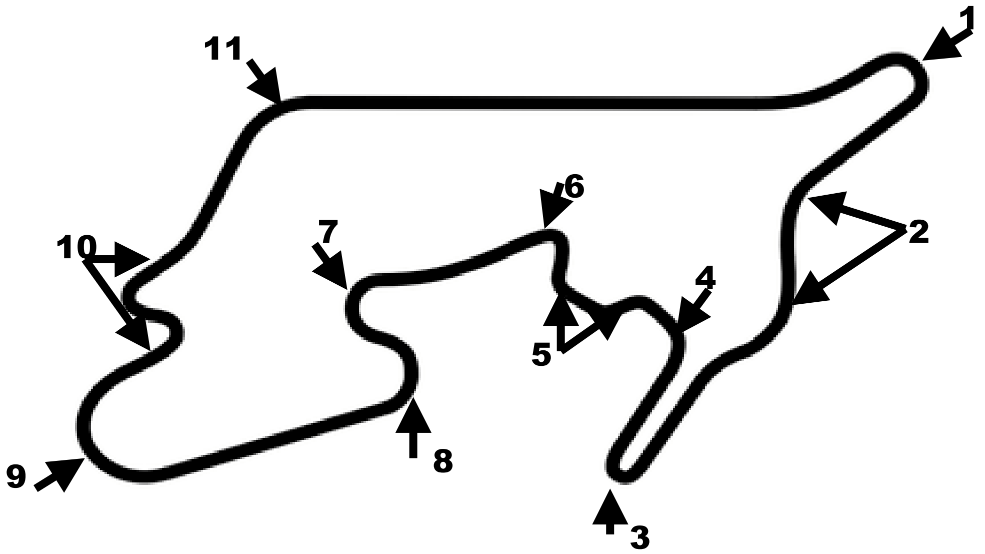
This now gives us the following corner rankings, from most important to least important.

Type 1a	**-**	**Fast corners that lead onto a straight**
Type 1b	**-**	**Medium corners that lead onto a straight**
Type 1c	**-**	**Slow corners that lead onto a straight**
Type 2a	**-**	**Fast corners that come at the end of a straight**
Type 2b	**-**	**Medium corners that come at the end of a straight**
Type 2c	**-**	**Slow corners that come at the end of a straight**
Type 3a	**-**	**Fast corners that connect two other corners**
Type 3b	**-**	**Medium corners that connect two other corners**
Type 3c	**-**	**Slow corners that connect two other corners**

When a corner could fall into two different types it will always be of the higher ranking.

Grand Valley Speedway - An Example

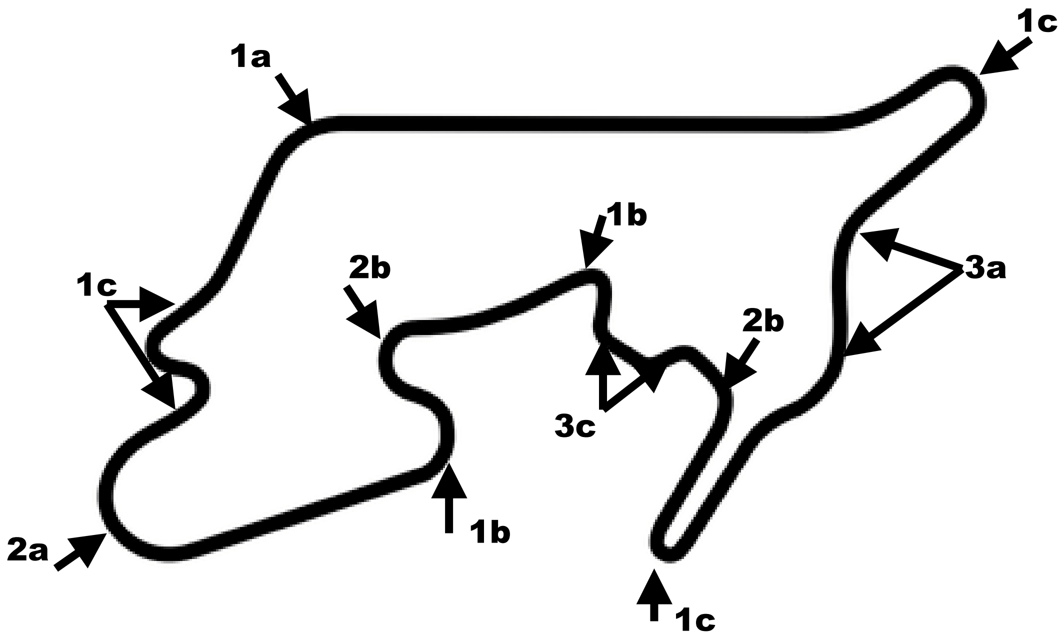
Now let's take a look at a track in Gran Turismo 4 and apply our ranking system to it and for this example we will be using the Grand Valley Speedway.



1. **This could be either a corner at the end of the main straight or the corner before the next straight. As already mentioned it will always fall into the higher ranking so this is a Type 1c – Slow corners that lead onto a straight.**
2. **This high speed chicane is made up of corners that link other corners and as such it is a Type 3a - Fast corners that connect two other corners.**
3. **As with corner 1 this hairpin could fall into two categories, so it again goes into the higher one, so is a Type 1c – Slow corner that lead onto a straight.**
4. **This left hander is quite clearly a Type 2b - Medium corners that come at the end of a straight.**

5. This very slow complex is a Type 3c - Slow corner that connect two other corners, and while tricky is rarely critical to overall laptimes. It is in fact the lowest ranking section of the track.
6. The left hander after the slow complex leads onto a short straight and as such ranks as a Type 1b - Medium corner that lead onto a straight.
7. This quite tricky left hander is a medium corner at the end of a straight and as such ranks as a Type 2b - Medium corners that come at the end of a straight.
8. And it leads straight onto this quite important corner, a medium right hand corner before a nice straight over the bridge, ranking as a Type 1b - Medium corners that lead onto a straight.
9. This fast sweeping right hand corner through the tunnel section ranks as a Type 2a - Fast corners that come at the end of a straight, and requires good throttle control to get around without running wide.
10. A tricky one to class this, at first glance its potentially a set of linking corners, but it does lead onto a straight, so it goes in the higher class. It's a Type 1c - Slow corners that lead onto a straight.
11. The final corner of the Grand Valley Speedway and a very high speed corner leading onto the longest straight on the circuit. The single most important corner on the track and the only 1a - Fast corners that lead onto a straight.

So if we apply our new ranking system to our map of Grand Valley Speedway its looks like this.



Now I'm quite sure that some of the people reading this will by now be saying, "that's rubbish corner x is a Type xx corner", and that's fine by me. The point of this section and the above exercise is to get you thinking about the very process of corner ranking. As I mentioned at the beginning the above method has been adapted and tweaked over the years for different people, and that's fine. Because more than anything else the simple act of thinking about the circuit itself and how one corner relates to the next and to your overall time is the single most important thing.

Example of a Tune

This example of a tune follows on from the one outlined in 'Making Progress' and uses a BMW M3 CSL at the Grand Valley Speedway, I would strongly recommend reading that example first as I will be using it as the starting point for this.

As a reminder here are the final settings I ended up with

Default		Setting	Scaff's set-up	
Front	Rear		Front	Rear
14.4	12.6	Spring Rate	12.5	11.6
84	84	Ride Height	79	79
8	8	Bound	5	4
8	8	Rebound	7	6
2	1	Camber	2	1
0	0	Toe	+1	0
5	5	Anti-Roll Bars	3	4
3	3	Brake Bias	4	3

Once again the car will be running stock as far as power modifications are concerned and on the standard S2 tyres. In addition to the Fully Customisable Suspension used last time I will be adding a wing, Fully Customisable Gearbox and Fully Customisable Limited Slip Differential.

I start with my settings from above and with the wing fitted I'm going to start with downforce (the FC gearbox and LSD I have not yet fitted.

I conduct a base run with the downforce set to zero front and rear to see what the car runs like and allow me to see the effect of my changes. Following this I put in a run with the front and rear set to 15, the result is a good increase in the grip of the car. Particularly in corners 9 and 11, but this aero balance is causing understeer on the limit at speed, which is very evident in the corner 2 section.

The front end of the car desperately needs more grip at speed, so I tweak the front end, raising it by a few clicks at a time until I get a balance of F20:R15. This seems to work a treat, so now to see how much downforce the car can take. I take a quick gamble and go straight to a F30:R25 setting and it works perfectly, the car now has gained a massive amount of grip at speed and has a nice neutral balance that leans towards understeer right on the limit. Its also made taking the all important turn 11 much easier, with the car remaining planted right around and out of it, making for very consistent runs.

I now slap on the Fully Customisable Gearbox and take the car for a run with the default Auto 13 setting. Its not too bad, but the acceleration could be better and the cars not making full use of fifth gear on the main straight. I step the auto down to 10 and give it a try, straight away the acceleration is much

better, quite happy with that. However were now running into sixth gear at the end on the main straight, so it's either keep the un-needed gear-change, bounce the engine of the rev limiter or fix the problem. I opt for the latter and tweak the final drive down to 3.4, which now lets the engine just hit the red-line in fifth as I reach the braking zone at the end of the main straight and keep the maximum speed here to around 150mph.

At this point its worth looking at the reason why I decided not to use sixth gear and tune to hit top speed at the red-line in sixth. It would seem like a sensible thing to do, and an auto slider setting of 7 will allow just that.

It does give slightly better acceleration in the lower gears and will still hit around 150mph at he end of the main straight. However its only just hitting the 150mph and the number of gear changes required around the lap has increased dramatically, so in very annoying places. The end result, for me, was that the car required more time changing gear, during which time you are not accelerating and overall was slower by approximately 1.5 seconds.

Right the final part, the Limited Slip Differential.

A quick test run after fitting the LSD immediately showed that it improved the cars stability under braking a great deal, actually too much. Also the car felt a little reluctant to turn under acceleration out of the two hairpin corners.

I first tweaked the Accel and Decel Values down to 35 and 15 respectively, the test drive revealed that this was a move in the right direction with the car happier to turn under both acceleration and braking.

However it still felt as if the differential was locking up a little early out of the two very tight hairpin and the final chicane (corners 1, 3 and 10), as these are all high ranking corners this was worth a further tweak to try and resolve. Back into the pits to set the Accel and Decel values to 30 and 10 respectively and back out to test.

This resulted in a big improvement in the required corners, with the car far more stable under braking and a lot more willing to change direction under acceleration. The trade off was a slight increase in instability into corner 1, but nothing to bad and well worth the gains in the other three corners for me.

The end result of all of the testing and tuning carried out to the M3 CSL over these two guides is that I now have a car that is more stable and more responsive. It's better able to put power down out of corners, and is able to carry more speed through faster corners. Perhaps most importantly it's also a car that has been built up around my driving style and requirements and as such feels tailored to my needs.

Making Progress

So what do the final settings look like:

Default		Setting	Scaff's set-up	
Front	Rear		Front	Rear
14.4	12.6	Spring Rate	12.5	11.6
84	84	Ride Height	79	79
8	8	Bound	5	4
8	8	Rebound	7	6
2	1	Camber	2	1
0	0	Toe	+1	0
5	5	Anti-Roll Bars	3	4
3	3	Brake Bias	4	3
0	0	Downforce	30	25
		Gears – Auto	10	
3.62		Final Drive	3.4	
10		LSD – Initial	10	
40		LSD – Accel	30	
20		LSD – Decel	10	

These changes have also given significant gains in lap times, all without a single power upgrade, weight reduction or change to a softer tyre compound. Obviously these changes would make the M3 CSL even quicker, but I hope that the example covered in these two guides has given you an idea of what you can do without changing the weight or power of the car. Now imagine what you will be able to achieve when all those upgrades are factored in.

Once again I hope that the last thirty odd pages have been worth your time and effort and I thank you for taking the time to read what I have to offer. And I just hope that it will be of use to you.

Regards

Scaff